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Dynamic separation has been investigated for various configurations and forcing dynamics. The details which differentiate 2-D vortex dynamics from those involve 3-D aspects were ~~have been~~ investigated. In additions, different dynamic stall control strategies have been tested.

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P.I. Professor Peter Freymuth

FINAL REPORT

TITLE: Dynamic Separation: Search for the Cause of Dynamic Stall and Search for its Control

During this period I have tried to get a handle on how dynamic separations occurs in various flow configuration and how the parameterspace influences these results. My work in this area included numerous 2-dimensional and 3-dimensional configurations and extensively used flow visualization methods. Furthermore, I tried a concept of stall control based on the premise that dynamic and static stall control are equivalent. I believe my work has proven the concept. In addition, the usefulness of dynamic stall for the hovering flight of insects has been demonstrated. My work in this period has been greatly enhanced by a leave of absence from the University of Colorado to the Seiler Laboratory, USAF Colorado Springs, where I was able to construct numerous experiments on hovering flight.

Numerous publications during this period and up to this time demonstrate best what has been accomplished, a list of which forms the meat of this report. I also enclose a recent talk which I presented at the workshop on the physics of unsteady separation at NASA-Ames in April 1990 and which contains the basic conclusions from my contract work.

In summary: In my judgement, the period August '88 to August '89 has been particularly successful in my research efforts on dynamic stall. A list of relevant publications (all publications are available upon request) and an enclosed workshop paper, document and sum up my activities.

1988 Papers by P. Freymuth

Propulsive Vortical Signatures of Plunging and Pitching Airfoils. Paper AIAA-88-0323, also AIAA Journal, Vol.26, pp. 881-883, 1988.

Three-dimensional Vortex Systems of Finite Wings. J. Aircraft, Vol. 25, pp.971-972, 1988.

Progress in Visualizing Unsteady Separation. Workshop II on Unsteady Separated Flow, Colorado Springs, pp. 197-210, 1988.

A Demonstration of Dynamic Stall Control (with S. Jackson and W. Bank). Flow Lines, Spring 1988, pp. 10-12.

Photograph featured in Turbomachinery Calenders, 1988 (May).

Aerodynamic Visualization for Impulsively Started Airfoils (with F. Finaish) La Recherche Aerospatiale 1988-4, pp. 55-62.

1989 Papers by P. Freymuth

1. Toward Dynamic Separations Without Dynamic Stall. Experiments in Fluids. Vol. 7, pp. 187-196, 1989

2. Thrust Generation by an Airfoil in Hovering Mode. F. J. Seiler Research Laboratory Report FJSRL-TR-89-0002.

3. Visualizing the Connectivity of Vortex Systems for Pitching Wings. J. Fluids Engineering, Vol. III, pp. 217-220, 1989

4. An Unsteady Model of Animal Hovering. Proceedings of Conference on Low Reynolds Number Aerodynamics, June 1989, University of Notre Dame pp. 229-240, Springer Verlag

5. Vortices. Handbook of Flow Visualization, Ch. 28, pp. 459 -479, Hemisphere Publication Corporation, 1989

6. Air Flow Visualization Using Titanuim Tetrachloride. Lecture Notes in Engineering, Vol. 45, pp. 1-31, 1989

7. Vortex Patterns of Dynamic Separation. Encyclopedia of Fluid Mechanics, N.P. Cheremisinoff Ed. Gulf Publishing, Vol. 8, pp.391-424.

8. Flow Visualization as a Challenge to and as a Reference for Computer Modellers. IMACS Transactions on Scientific Computing, Vol. 1.1, pp. 231-236.